Dynamic population gratings in highly doped erbium fibers

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1. Introduction

Dynamic gratings can be recorded in an erbium doped fiber (EDF) by two counter-propagating coherent laser beams resonant with the transition between the ground and the metastable states of the erbium ions. The grating is produced through spatial selective saturation of the fiber absorption in the bright fringes of the interference pattern. Since this process is associated with a redistribution of the population between both states, these dynamic gratings can be addressed as dynamic population gratings. These gratings lead to an increase in the intensity of both transmitted beams since the diffraction of the backward beam on the grating adds constructively to the transmitted forward beam, and viceversa. The first experimental observation of dynamic gratings recorded in EDFs was reported less than two decades ago by Frisken [1]. After that, applications of such gratings in single-frequency cw fiber lasers, tunable narrow-band fiber filters, and in adaptive interferometry have been proposed (see review [2] and references there in).

In this work, we study the effect of ion concentration in the dynamic population grating recorded in highly doped erbium fibers (HEDFs). In order to characterize the dynamic grating, we performed a transient two wave mixing (TWM) experiment applying a square phase modulation with a jump of π in one of the recording waves [3]. Thus, the transmitted power of each beam shows transitory negative peaks which decay with the characteristic time of the grating formation [2]. Stepanov et al. [4] found that the grating formation time is in the order of the lifetime of the metastable level (10.5 ms) although it decreases with ion concentration due to spatial migration of excitation. We analyze in detail grating efficiency in terms of the amplitude of that transitory negative peaks as a function of input power.

2. Results and discussion

Fiber label	Absorption coefficient (dB/m)	Ion concentration (ppm)	Fiber length (m)	Optical density
Er20-1.0	20	800	1.0	3.8
Er30-1.0	30	1050	1.0	5.0
Er40-1.0	40	1350	1.0	6.4
Er80-1.0	80	3150	1.0	15.0
Er80-0.2	80	3150	0.2	3.0
Er80-0.3	80	3150	0.3	4.5
Er80-0.5	80	3150	0.5	7.5

Table 1: Fiber properties

The experimental dependence of the TWM relative amplitude on the recording power is shown in fig. 1 (a) for fibers with different ion concentration (see fiber properties summarized in Table 1).

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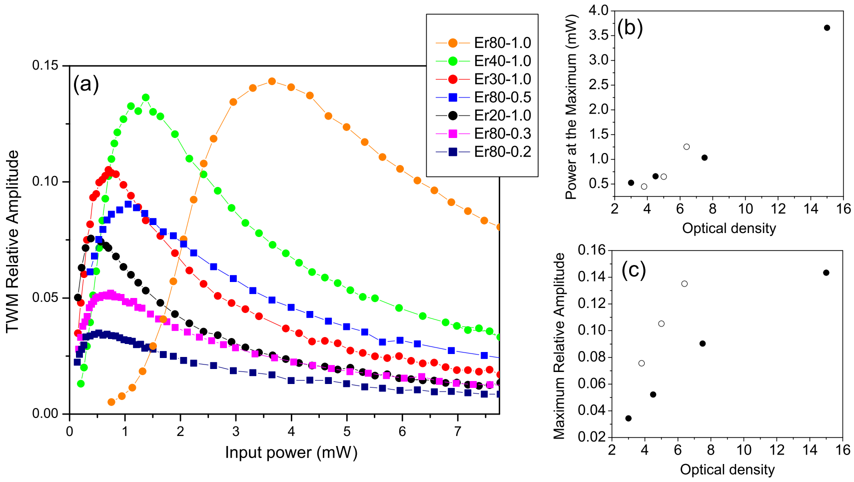

Figure 1: (a) TWM relative amplitude as a function of input power for fibers with different ion concentration. Maximum relative amplitude (c) and power at that maximum (b) as a function of optical density. For (b) and (c): Moderate doped fibers (open circles); highly doped fibers with ion concentration of 3150 ppp (closed circles).

For each fiber, a maximum TWM relative amplitude is obtained close to the saturation power of the fiber. Thus, the power at which the maximum is attained increases with optical density (see fig. 1 (b)). Furthermore, the maximum relative amplitude obtained for each fiber is not increasing with optical density as expected (see fig. 1 (c)). In fact, highly doped fibers with ion concentration of 3150 ppm (closed circles) deviate from the behavior found for moderate concentrated fibers (open circles). In particular, highly doped fibers exhibit lower TWM relative amplitude. This seems to indicate that inter-ion interaction effects which appear at high dopant concentration are responsible of the grating efficiency decrease. We have theoretically analyzed the effect of the cooperative upconversion process that occurs in closely located erbium ions (ion clusters) on the TWM response. In that case, the clustered ions record a grating which generates a diffracted beam that adds destructively with the beam diffracted by the usual grating (the one recorded by the isolated ions), so that the total diffracted beam decreases.

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